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MOVEMENTS OF HAPLOCHROMINES (PISCES: CICHILIDAE) IN LAKE GEORGE, UGANDA.

J.J. GWAHABA
Department of Zoology, Makerere University
P.O.Box 7062, Kampala, Uganda.

ABSTRACT

In Lake George, the abundance of haplochromines in inshore regions during the day and at night differs significantly. Futhermore, while by day there are more haplochromines in the lower than the upper layers, at night these fishes appear to be uniformly distributed throught the water column. Regions of the lake near river mouths had fewer haplochromines during the wet than the dry season, while the reverse was true of regions distant form the river mouths. Possible causes of these movements are discussed.

INTRODUCTION

Lake George (Fig. 1) is a shallow eutrophic equatorial lake situated in Western Uganda, in the western branch of the African Rift valley. The annual rainfall in this region, which falls chiefly in April and October, is 82 cm per annum.

Most of the inflow comes from the snow capped Rwenzori mountains which receive an annual rainfall of ca 200 cm.

Contributions of melt water from the snow are enhanced in the warmer dry seasons, thus reducing the seasonal range of fluctuation by increasing the otherwise low dry season flow (VINER and SMITH, 1973). The water from the mountains and the rift wall enters the lake by several rivers, the most important being the Rukoki/Kamulikwezi, Sebwe, Mubuku, Nsonge, Mpanga and Buhindagi. The 36 km long and 1km wide Kazinga channel is the lake's only outflow draining into Lake Edward.

The water of Lake George has a pH range of 8.5 - 9.5 (VINER, 1969), and supports a perennially dense algal crop 80% of the biomass of which is made up of blue-green algae, Cyanophyceae. The algae reduce light penetration into the lake, the euphotic zone being about 70 cm (GANF, 1969).

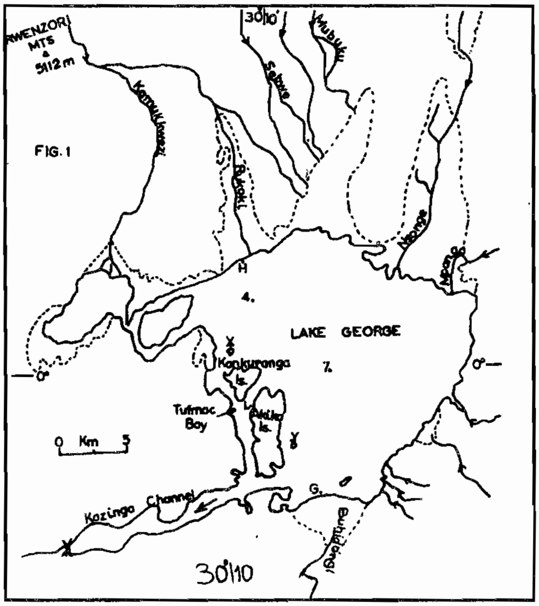

Fig. 1. Sites sampled in the study.:
Offshore sites - 4 and 7.
Inshore sites - G, H, L, X, Y.

As a result, the concentration of oxygen at the surface may rise to well over 200% saturation, while near the mud surface it may range from 20 - 40% saturation.

Water temperatures remain high throughout the year. The deeper layers have about the same temperature as the air, 23 - 25°C, but the surface waters heat up progressively during the day to between 30 and 33°C (exceptionally to 35°C), so that extreme thermal stratification results. Thus the vertical temperature gradient can be up to about 10°C within 2.4 m. At night surface cooling and the resulting convection currents, some times assisted by breezes, causes mixing of the lake throughout the water column (VINER and SMITH 1973). Under conditions of complete mixing temperatures range between 25 and 26°C (DUNN et al, 1969).

MATERIALS AND METHODS

At least 32 species of fish occur in Lake George, 17 of which belong to the haplochromine species flock. Two of these *Enterochromis nigripinnis* and *Gaurochromis angustifrons* are numerically predominant. Four species are found in virtually all areas of the lake; the rest have restricted ranges near the shore (Appendix).

Fish were caught for this study with a purse seine, a beam trawl and monofilament nylon nets with a stretched mesh of 30 mm. The purse seine was 46m long and 9m deep, the top 4m being made of a 10mm mesh net, and the lower of a 30mm mesh net. The beam trawl was 1m deep and 1.5m wide, with a 10mm mesh (stretched) codend.

RESULTS

Vertical Movements

Trawling was done 100 - 200 m from the shore in Tufmac bay at 2 hours' intervals. The trawl which was only 1 m deep and was floated at the surface, was fishing a depth of 1 m below the surface. The samples obtained by day contained fewer *G. angustifrons* than those in samples obtained at night (Fig. 2). Although the numbers of the phytoplankton feeder, *E. nigripinnis* varied in a similar way to those of *G. angustifrons* by day the samples contained more *E. nigripinnis* than *G. angustifrons*. The numbers of *E. nigripinnis* caught in the morning were high but decreased gradually until mid-day when they started increasing again until evening

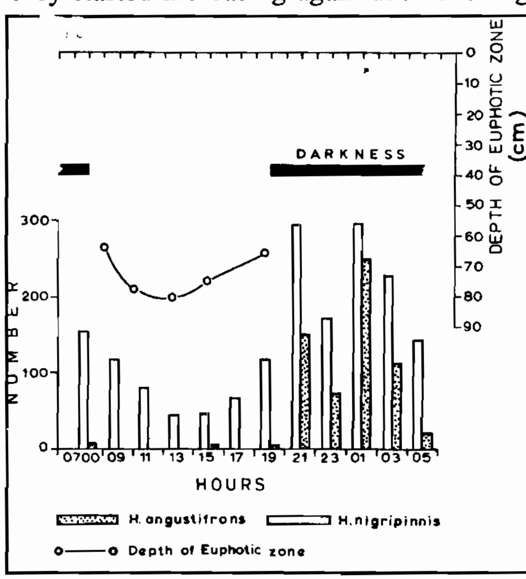

Fig. 2. Variation in numbers of *Gaurochromis angustifrons* and *E.nigripinnis* in ½ minute trawl samples btained about 100m from shore in Tufmac bay. Variation in euphotic depth recorded at a mid-lake site. (GANF, 1969).

(Fig. 2).
Furthermore the mid-day samples contained proportionally more young than in the morning and evening samples so that the mean weight of *E. nigripinnis* in the samples varied in a way similar to that of numbers. To test whether these changes were a result of some adult moving towards the bottom water layers by day, two 30 mm mesh (stretched) monofilament nylon nets 1.25 m deep were set in Tafmac bay one at the surface and the other at the bottom but in adjacent positions. These were lifted at two hour intervals for 24 hours. By day, more haplochromines were caught in the net set at the bottom than in the one set at the surface (Fig.3). In the euphotic zone, the surface set net caught very few haplochromines. This suggets that the majority of these fish were present in the aphotic zone. Similar results were obtained from Site X (Table 1). The obvious conclusion is that some of these fishes move downwards by day.

Daily movements towards the shore

In May 1971, 31 trawl samples were obtained at dusk and at dawn from Site X. The water in this region is only 1.0 - 1.5m deep and the trawl caught fish from virtually the whole water column. As the light intensity decreased at dusk there was a rise in catches of haplochromines but as the light intensity increased at dawn, there was a corresponding fall in catches. Data from Tufmac Bay show similar trends (Fig. 2). Similar results were obtained in experiments where a spirally operated seine used at Site Y (DUNN, 1972). On the basis of his and the present experiments, it would appear that haplochromines increase and decrease in abundance at dusk and dawn respectively in all shallow regions of the lake. In the samples from gill-nets at the bottom and the surface in Tufmac Bay, there was a rise in catches only at dusk and dawn (Fig.3), indicating increased activity of haplochromines at these times. These facts suggest movement of fishes in and out of the shallow regions at dusk and dawn.

Table. 1 The number of fish caught in surface and bottom set 30 mm mesh (stretched) monofilament nylon nets. Nets set at 0900 hours and lifted at 1430 hours local time, on 29th May, 1971.

Sites	Species	No. of Fish in Surface net	No. of Fish in Bottom net
x	*E. angustifrons* *E. nigripinnis*	61 16	117 22
300m north of site x	*E. angustifrons* *E. nigripinnis*	3 4	102 26
	Total	84	267

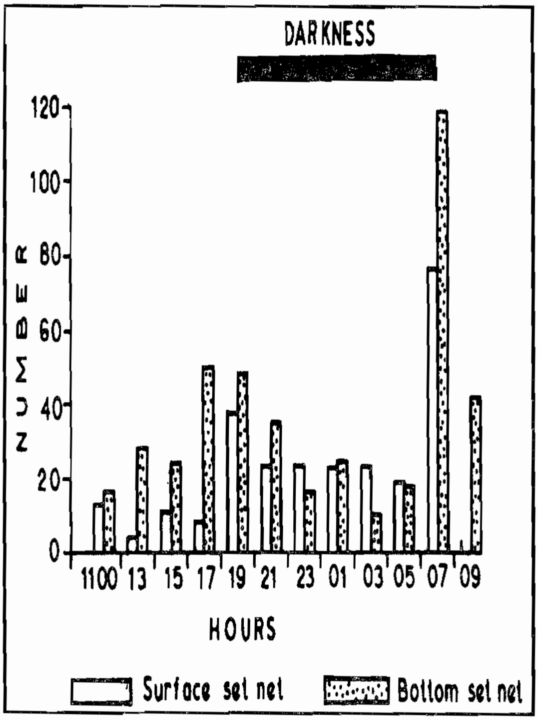

Fig. 3. Variation in numbers of haplochromines in surface and bottom-set 30 mm mesh (stretched) monofilament nylon nets. Nets set about 150 - 200 m from the shore in Tufmac bay on 7th June 1972.

To investigate the origin of the haplochromines that were making the movements, the purse seine was used. At the inshore Site L three stations were established, one at 10m, another at 100m, and the third at 300m from the shore. From each, one sample of fish was obtained by day and one by night. Comparative samples were obtained from the offshore Site 7. The mean biomass figures for the day and night samples from Site L were 15.4 $\pm$ 5.2 g/m^2 and 35.3 $\pm$ 4.6 g/m^2 respectively. The figure of the night samples is significantly larger than that of day samples ($p < 0.001$). These differences are also evident in the length frequency analyses of *E. nigripinnis* and *G. angustifrons* (Fig.4). There is also evidence that these fishes migrate to inshore regions from nearby offshore regions; for example, the increase in numbers of juveniles of *E. nigripinnis* at the 10 m station corresponds with the decrease at 100 m and 300 m stations.

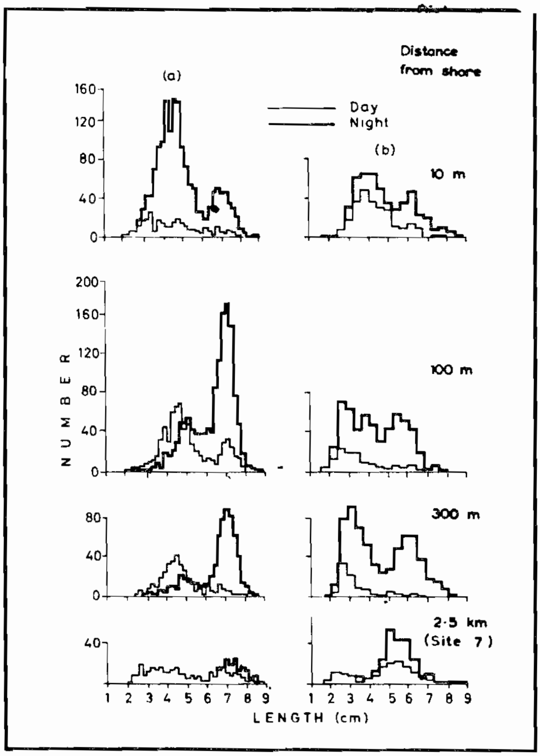

Fig. 4. Numbers of (a) *Enterochromis nigripinnis* (b) *Gaurochromis angustifrons* in one seine sample obtained by day and by night from stations at site L and from site 7.

The mean biomass figures for the day and night samples from sight 7 were 6.6 g/m^2 and 15.9 g/m^2 respectively, the difference being insignificant considering the wide variation between replicate samples encountered on other occasions (the standard error varied between $\pm$ 0.7 and $\pm$ 3.3 g/m^2: $p > 0.05$ for higher values). Presumably fishes in distant offshore regions do not take part in this movement towards the shore.

Figures for the rarer species with a lakewide distribution are difficult to interprete due to the insufficient sample size of specimens (Table 2). In day samples at Site L, the number of specimens per 5 samples varied between 1 and 5 for *Yssichromis pappenheimi*, and between 28 and 78 for *E. squamipinnis*.

Table 2. The number of fish of the less abundant haplochromine species from purse seine samples obtained from two sites.

Site	Species	Day	Night
L	*E. squamipinnis*	36	36
	Y. pappenheimi	44	44
7	*E. squamipinnis*	2	5
	Y. pappenheimi	3	2

The above data indicate that *G. angustifrons, E. nigripinnis and Y. pappenheimi* move towards the shore at dusk. However, some inshore species of haplochomines seem to migrate in the opposite direction. At night, *Astatotilapia aeneocolor, A. elegans, Haplochromis limax, Psammochromis schubotzi, A. schuboziellus, Lipochromis taurinus* and several others were frequently caught in a region 50 - 400 m from the shore.

On moonlit night, the fish trawled were fewer and represented fewer species than on dark or cloudy nights. This suggests that bright moonlight may have some inhibitory effect on the movement of haplochromines.

Seasonal Movements

Attention was paid to seasonal changes in numbers, biomass and population structure of haplochromines in different regions of the lake. This study was carried out at two open lake sites (4 and 7)and three inshore sites (G, H, and L). Site L is close to Site X where a similar study was carried out by DUNN (1972) using gillnets, and his results are used for comparison.

The study period included one dry and two wet seasons, and sampling was done once or twice a month. On each sampling trip, using a purse seine, 3 to 5 samples were obtained from each of the five sites. 213 samples were collected in all.

At the two offshore sites, the relatively large differences between the mean biomass figures obtained between October and December 1971 are likely to have been due to a faulty method of choosing positions from which to obtain replicate catches, which was later corrected. Since the variation between replicate samples is large, giving a standard error of $\pm$ 0.7 to $\pm$ 3.3 g/m^2 for Site 7, and $\pm$ 0.8 to $\pm$ 1.5 g/m^2 for Site 4, the variations in fig. 5 are not significant.

On the other hand, relatively large change in biomass and numbers of haplochromines were observed at inshore sites. The variation between replicate samples results in a standard error of $\pm$ 0.6 to $\pm$ 5.9 g/m^2 for Site G, $\pm$ 0.5 to $\pm$ 4.0 g/m^2 for Site H, and $\pm$ 0.8 to $\pm$ 4.7 g/m^2 for Site L. Taking the highest values of standard error, it can be seen from Fig. 5 that the differences between the highest and lowest mean biomass figures is significant ($p < 0.01$) for all the three sites, as evident also in the length-frequency analysis for the major species, *E.nigripinnis* (Fig.6). At Site G, there was a decrease in the number of juveniles of *E. nigripinnis* during the September-November 1971 wet season,and of both juveniles and adults in the March-May 1972 wet season. During the dry season of December 1971 - February 1972, there was an increase of adults, while the June - August dry season was characterised by by large numbers of juveniles. Another increase in the number of juveniles which took place between February and April 1972 can probably be explained by recruitment. During this period , there were many breeding females. However the other changes outlined above can be explained only by movements. It is likely that some *E. nigripinnis* were migrating away from the region around Site G during the wet season and back during the dry season. Since the numerical changes of *G. angustifrons* and other haplochromine species were virtually similar to those of *E. nigripinnis*, these species too could be moving about in a similar way.

At the northern site H, the sequence of events was slightly different (Fig. 5). Here, the decrease in numbers of haplochromines occured at the beginning of the two wet seasons and by the middle of the seasons the numbers were high again.

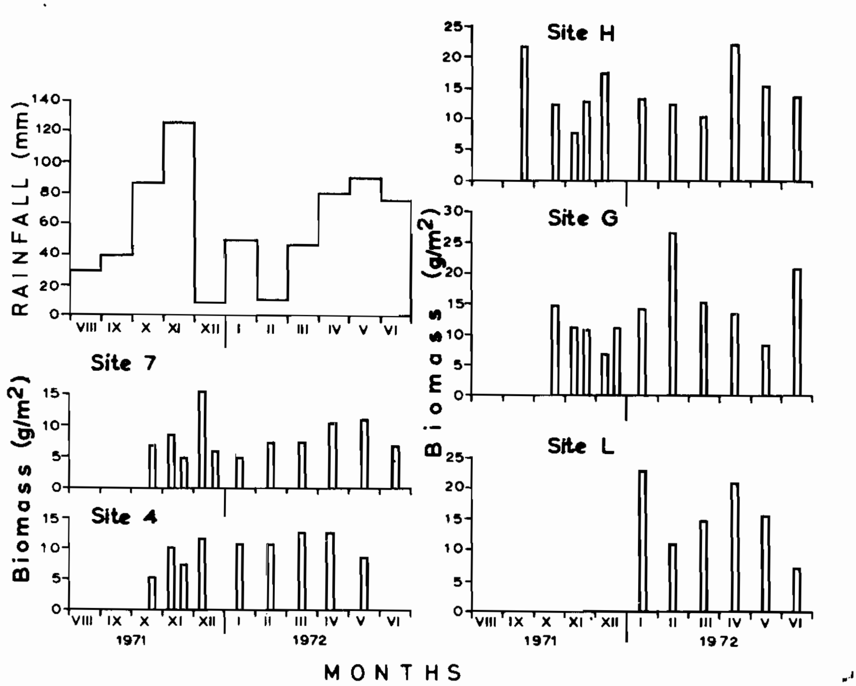

Fig. 5. Variation in biomass of Haplochromines at several sites (see Fig. 1.). Rainfall figures are for the IBP Research Station, Kasenyi.

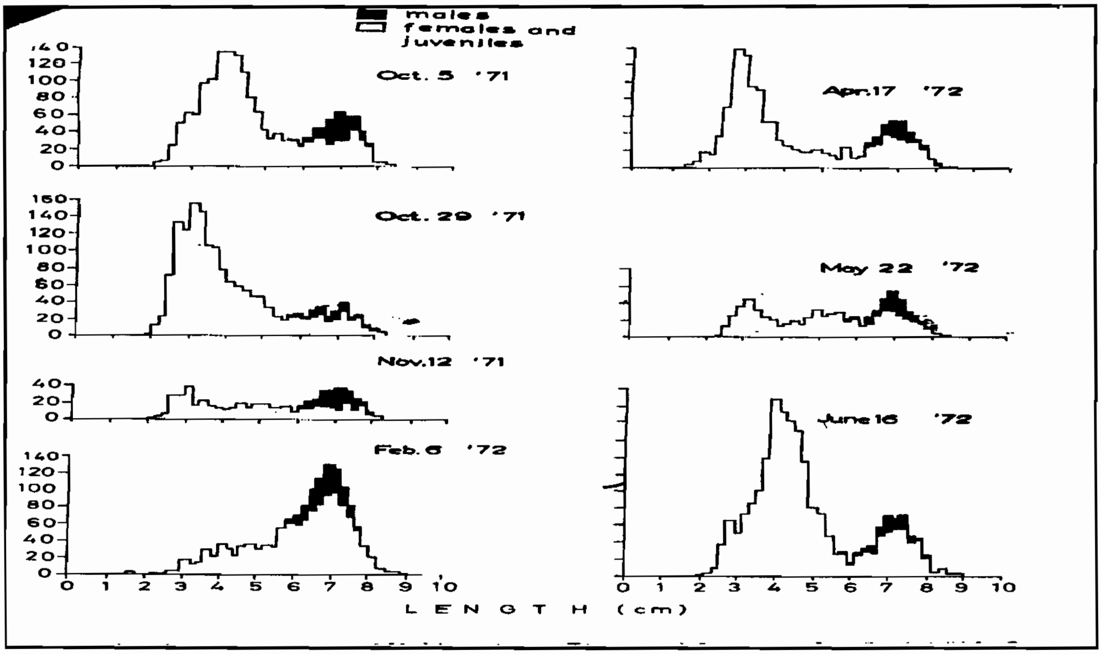

Fig. 6. Variation in numbers of *Enterochromis nigripinnis* in seine samples obtained from site G between October 1971 and June 1972.

However, at Site L. the changes in numbersof haplochromines were in reverse to those of samples obtained from Site G. It may be that these fishes move to the region around Site L. during the wet season and away during the dry season. This suggestion is supported by similar observations which were noted by DUNN (1972) at Site X which is near Site L.

DISCUSSION

The depth of the eutrophic zone in lake George varies throughout the day as a result of changes in incident radiation. Light penetration also depends on the distribution of particular matter, especially algae and other material. Thus the eutrophic zone is shallow in the morning and evening and deeper around midday (Fig. 2). By moving downwards as the eutrophic zone deepens, haplochromines avoid this brightly lit region. As the deeper water is almost permanently well oxygenated as a result of daily mixing , it is possible for them to live near the bottom, feed and reproduce there.

Another factor which may have an effect on the vertical distribution of haplochromines in lake George is oxygen concetration. The high concetration of oxygen is a result of photosynthesis. The effect of this super-saturation on haplochromines is not known. In the literature, there are conflicting reports on the effect of such super-saturation in fishes. Whereas the death of fish in a Wisconsin lake (WOODBURY, 1942), in ponds supersaturated as a result of photosynthesis, and in fish containers fitted with oxygenated apparatus (MANN, 1952; HARNISH, 1951; SCHAEPERCLAUS, 1954) was attributed to oxygen supersaturation, up to 32% in some cases, labolatory tests on fish in aquaria did not produce any ill effects, even when the saturation was raised to 300% (*WIEBE and McGAVOCK, 1932). In any case, even if supersaturation had no adverse effects on haplochromines, they could prefer the lower oxygen concentration in the aphotic zone. Similarly, they prefer the lower pH below the euphotic zone to that in the euphotic zone. Further more a factor such as temperature may have a profound effect on the fish's physiology. During the day when the thermal stratification develops, the high surface temperature of 30° - 33°C raises the respiratory rate of the fish and causes them to expend more energy than they would in the aphotic zone.

Although the vertical movements may be stimulated by changes in physical-chemical factors, there appears to be no evidence at present that the same factors are the cause for the movement towards and away from the shore at dusk and dawn.

Dusk and dawn trawling at Site X revealed that rapid changes in the numbers of haplochromines were synchronised with changes in light intensity, and took place between 19 00 and 20 00 hours, and between 06 00 and 07 00 hours. On moonlit nights the number of haplochromines that moved towards the shore was lower than on dark nights. This suggests that they can detect low illuminations.

The rapid change in light intensity at dusk and dawn probably is the signal for the start of the movement. However the cause for the movement is not known. It may be related to shoaling activity. Alternatively, since *G. angustifrons* (DUNN, 1972) and *E. nigripinnis* (MORIARTY and MORIARTY, 1973) and possibly other haplochromines too feed more intensively by day than at night, this movement may be a simple form of homing behaviour which they perfom after a days foraging is over, and return to a region where they prefer to spend the night.

Similar dawn and dask movements of fish have been observed in other lakes. In lake Kariba fish move to coves at dusk and away from them at dawn (BALON, 1972).

The causes of seasonal movements of haplochromines can probably be explained by noting the time at which migration occurs as well as the conditions prevailing in the particular region. Additional information is provided by the results of the general survey of fish distribution in Gwahaba (1975). In this survey, it was observed that dilution of the plankton by riverine water from River Nsonge probably caused a reduction in numbers of haplochromines near the river mouth. Here scacity of fishes seems to be related to the low density of algae, resulting also in the increased transparency of water. Perhaps temperature too is involved. It is likely that all these factors combined may be the cause of seasonal movements of haplochromines. During the wet season, rivers flow into Lake George all-round the northern, eastern and southern regions. Only the western shore is not affected by this water. The affected area is large, and

* From Macan, 1969.

a movement of part of the population of haplochromines from it may be responsible for the rise in abundance of these fishes in the unafffected western region (where Sites L and X are situated).

The dry season, when less water enters the lake, haplochromines move back closer to the rivers. However, an exception is the movement at Site H, where haplochromines move away at the beginning of the wet season, but by the middle of the same season, they move back. This difference in the time of movement may be caused by difference in the transparency of water of the Rukoki and Buhindagi rivers. Water flowing from the Rukoki river into the region of Site H is light brown, and this colour is intensified at the beginning of the wet season. Later in the wet season it darkens until it is dark brown almost black. Therefore, by the middle of the wet season, the water at Site H has this dark brown colour, and is less transparent than that which is present at the beginning of the wet season. At the beginning of the wet season, haplochromines move away from Site H when plankton become diluted and the transparency of the water is increased. Later on when the transparency has been reduced by dark brown water, they return to this area. This is in contrast with the situation at Site G where the water from the Buhindagi river, though it has diluted the plankton during the wet season, retains its light-green colour until the middle of the wet season when it turns only slightly brown. Here, haplochromines move away at the beginning of the wet season and move back at the end when the water has a lower transparency and plankton is more concentrated.

If at the beginning of the wet season, the low density of the algae at Sites H and G is the cause for emigration of the phtoplankton feeder *H. nigripinnis*, then these fishes would, probably return to these sites at the end of the wet season when algae are more concentrated. On the contrary, at Site H, *E. nigripinnis* return in the middle of the wet season when the density of algae is still low. It is possible that this movement is related to the changes is water transparency. *E. nigripinnis* moves away from both sites at the beginning of the wet season when the water has a relatively high transparency, and back to Site H in the middle of the wet season and Site G at the end of the wet season when the transpaency is lower.

The effect of riverine water on the numbers of benthic insect larvae, which are the food of *G. angustifrons* and several inshore haplochromines is not known. But since the timing of the movement of these species is similar to that of *E. nigripinnus*, it is possible that they too move as a result of transparency changes. It therefore seems that haplochromines make these movements to avoid the brightly lit regions of the lake.

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Appendix: Regions inhabited by, and food preferences of *Haplochromis* species in Lake George.

Species	Region	*Food
Gaurochromis angustifrons	Whole lake	Insect larvae
Enterochromis nigripinnis	"	algae
Ysschromis pappeniheimi	"	Zooplankton
Harpagochromis squamipinnis	"	Small fish
Astatotilapia elegans	Inshore	Insect larvae
Psammochromis schubotzi	"	"
Astatotilapia schubotziella	"	"
Astatotilapia macropsoides	"	"
Astatotilapia aeneocolor	"	Detritus
Haplochromis limax	"	Aufwuchs
Labrochromis mylodon	"	Molluscs
Lipochromis taurinus	"	Eggs, embryos and other fish
Schubotzia eduardiana	"	Scales
Astatotilapia eregosoma	"	Algae?
Paralabidochromis labiatus	"	Unknown
Astatotilapia nubila	"	"
Thoracochromis petronius	Rocky shores	Insect larvae

*Only the main items of food are presented. Information from Dunn (1972) and Greenwood (1973).